Heavy Neutral Leptons at Accelerator Neutrino Experiments

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Outline

- Motivation, theory
- HNL production
- HNL signatures and backgrounds
- Outlook and plans

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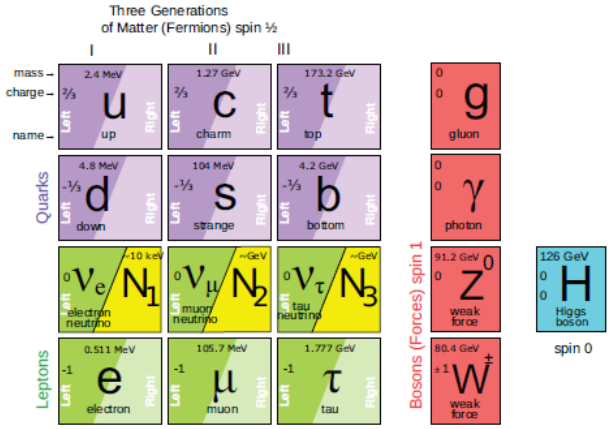
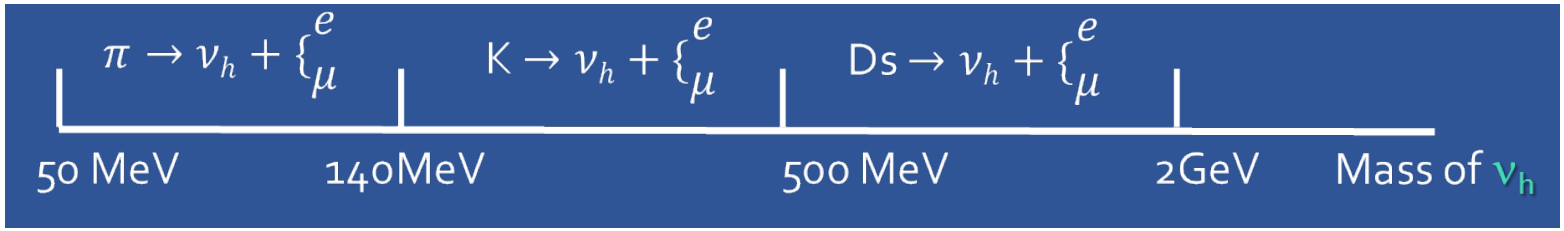
Intro to Heavy Neutral Leptons



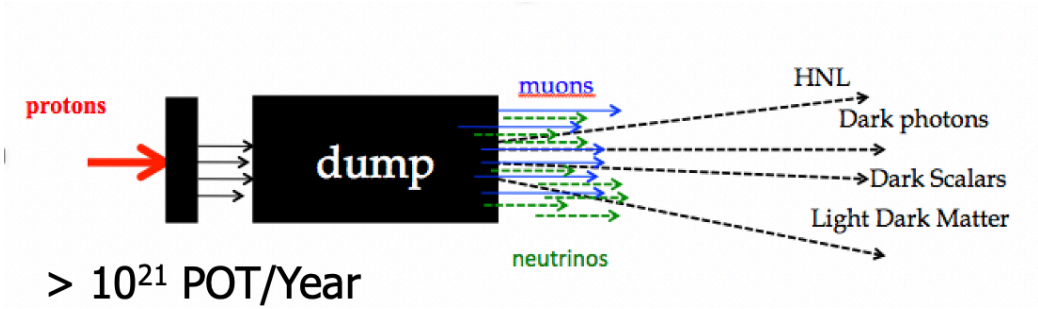
- They are an extension the SM with 3 new HNLs
- Right-handed partners singlets.
- Lightest members of a Hidden Sector.

Eg: νMSM arXiv:hep-ph/050513

- Address the smallness of the neutrino masses and the baryon asymmetry, Dark Matter…
- Interest in the phase-space region consistent with cosmological and astrophysical bounds.



Production of HNL

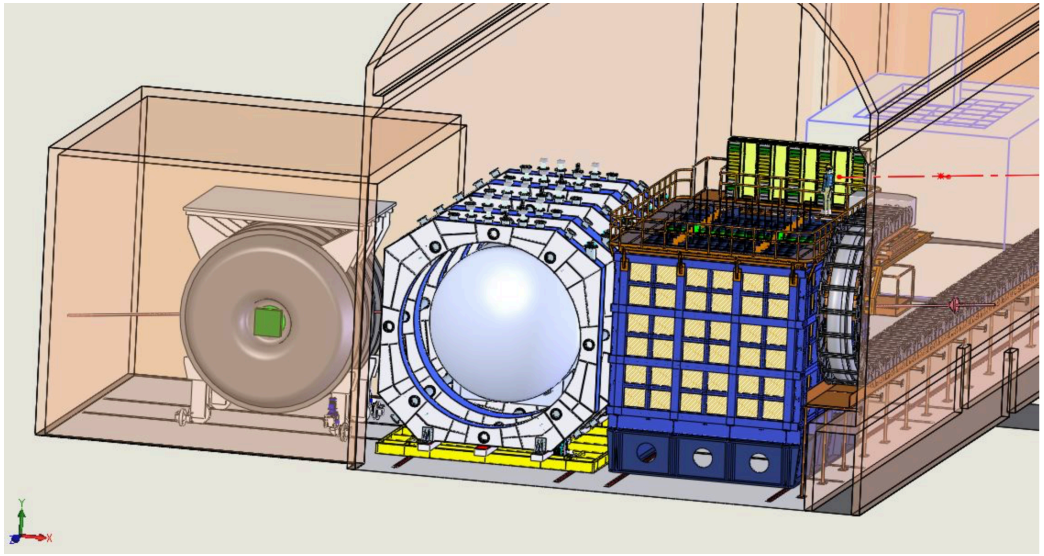


Our interest is focused on a specific process.

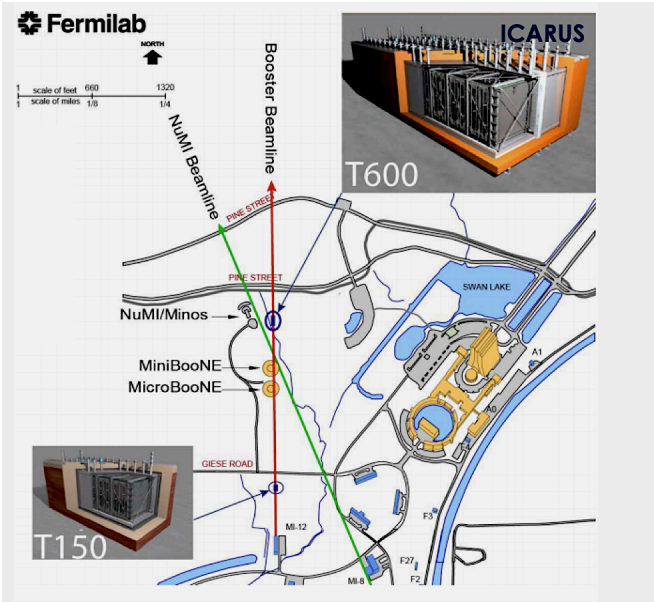
- Source: the accelerator-based neutrino beam facilities.
  - Primary focus: DUNE-LBNF proton accelerator, ICARUS/NuMI beam.
- Location: the target producing the secondary beam.
- Parents: the mesons and leptons of the secondary beam.
  - Muons, pions, and Ds mesons.
- Detection: at the short baseline detector systems.
  - Primary focus: DUNE Near Detector, especially the ND-GAr.

Detectors /opportunities in neutrino experiments

DUNE near Detector:
Distance 574m
80/120 GeV protons
Detectors: LArTPC and high pressure GArTPC
On/off axis ~50%/50%



ICARUS @NuMi:
Distance: 100/800m (target/absorber)
120 GeV protons
Detector: LArTPC Off axis by 6^0



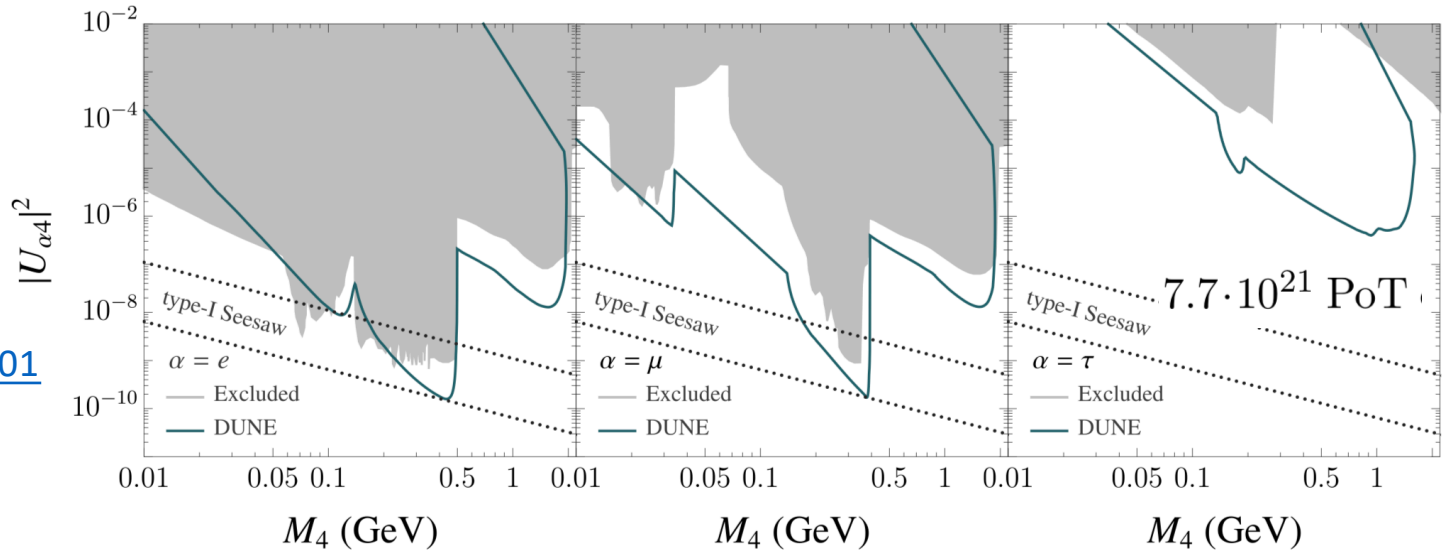
Such analyses have been already performed in eg T2K, MicroBooNE; under way in NOvA…

Initial sensitivity studies for LBNF/DUNE

- P. Ballet et al. 1905.00284
- J. Berryman et al. 1912.07622
- P. Coloma et al. 2007.03701
- DUNE Near Detector CDR (in progress)

Representatives of all these studies are takening part in this LOI effort

2007.03701



Signatures/Backgrounds and Tools

- Decay channels (examples)

$$\text{HNL} \to e\pi, \nu e\mu, \nu ee, \nu\mu\mu, \nu\pi^0, \text{ and } \mu\pi.$$

- Main backgrounds
  - Neutrino-Nucleon scattering - when hadronic output below detection level.
  - pion production in charged current-neutrino scattering
  - Mis-identification of long pion tracks as muons; Neutral pions.
- Tools for the study ->
- Generation of signal events
  - Use the up to date LNBF/DUNE neutrino flux files
  - HNL production in channels with neutrino decays, using FeynRules+Madgraph, according to the prescription given in 2007.03701
  - GENIE interface with simplified HNL decay kinematics for fast studies
- Detector simulation (DUNE-ND context). Detailed simulation and reconstruction, under preparation in the DUNE-ND group. For singal + background
- Transport the generation tools for exploratory ICARUS/NUMI study.

Outlook and Plans

- Sensitivity studies for in-flight HNL decays up to 2 GeV mass.
- Detailed simulations on backgrounds.
- Explore possible additional experimental handles (timing…)
- Use of LBNF flux files for various total power scenarios.
- Exploratory study for ICARUS/NuMi, SBND..
- Non-minimal HNL models/ Non-standard decays via (examples)
  - dark Z0, HNLs as portals to dark sectors
  - dipole moments,
  - B-L gauge boson,…
- Open for collaboration with more interested people, on these or similar ideas for searches for HNL